Slow Ground Motion and Alignment System

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1. INTRODUCTION

An active supporting table was developed for the Accelerator Test Facility (ATF) damping ring and general studies about the system are undertaken to test the quality for long term use [1]. ATF consists of 1.54 GeV electron linac and a low emittance damping ring to test and verify many crucial elements of future linear collider, which is JLC [2]. Quantitative description on the supporting table has been given in several workshops. Then this paper presents mainly the slow vertical ground motion, a special hydrostatic leveling system and a control system using Local Operating Network (LON). The power spectral density of the ground motion was studied in relation to the construction of large scale and high luminosity machines [3, 4]. The tolerance for errors of the ATF ring is 50 μm for vertical displacement and 500 μrad for rotation [5]. In conclusion, we have to realign at least 100 μm/month for the damping ring.

2. SLOW GROUND MOTION

2.1. Wide Band Empirical Power Spectrum Law

A long term drift and slow fluctuations of the vertical ground motion were studied in the KEK TRISTAN tunnel and a mountainside tunnel to get the detailed power spectral density [3, 4]. We use a water-tube-tiltmeter to get the spectrum below 1 mHz [6]. We also use a broadband seismometer (Streckeisen STS-2) to get the spectrum from 10 mHz to 100 Hz. Both power spectra give possible data to estimate the ground motion amplitude for wide frequency band. The result of long term measurements by the tiltmeter is analyzed by the computer program, BAYTAP-G [7]. This program is a method for tidal analysis based on the concept of Bayesian statistical modeling. BAYTAP-G decomposes the input data into a tidal part, a drift part, a response part and an irregular part under the assumption that the drift is smooth. The changes in underground water triggered by the precipitation act as a significant cause of the drift. It was not rare that the amount of drift due to precipitation of 100 mm reaches to the value of the order of 1 μrad [4, 8].

We have given that a simple and empirical power law equation on the spectrum for the ground motion can be roughly characterized by $10^{-9}(1/f)$ m/√Hz between 10^{-9} Hz and 10^{-3} Hz [4]. This proportional coefficient changes with site dependence from 10^{-9} m/√Hz to $1.5*10^{-8}$ m/√Hz. The ground-noise spectrum in the frequency range of 10^{-2} Hz to 100 Hz is very complex. It is roughly expressed by $1.9*10^{-9}*(1/f)^{1.4}$ m/√Hz on the quiet site. This proportional coefficient on the noisy site is multiplied by a factor of 10-50. In the actual accelerator tunnel, the power spectrum is superimposed with the noises of various sorts as followings:

(1) vibration induced by cooling system,
(2) ambient temperature change,
(3) ocean swell around 0.2 Hz,
(4) noises of human activity
in the frequency range 1 to 100 Hz,
(5) crustal resonance around 3 Hz.

Differences in geological and topographical properties may cause block movement in some case and may change the amplitudes [9]. Inhomogeneous structure of the ground and the tunnel plays an important role in the ground motion process, which is a rapid stress relaxation by fracturing and the seismic wave scattering.

2.2. Spectrum and Correlation at ATF

In order to estimate the power spectral density on the ATF tunnel, we began to measure microseismic noise using two STS-2 seismometers. There are 11 expansion joints on the floor structure around the tunnel. In other words, there are 11 islands within the beam line. The joints are essential for preservation of the tunnel from destruction by thermal strain or ground motion. We measured power spectra and correlations between the two seismometers as a function of the distance and number of expansion joints. Figure 1 shows power spectral density observed by the two seismometers at a distance of 48 meters. There is no difference between the

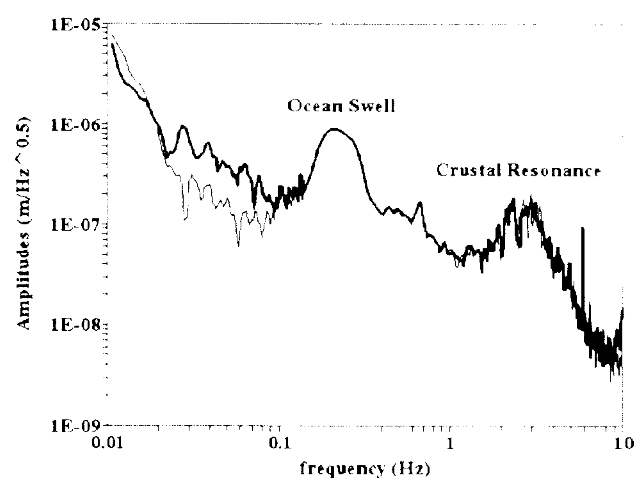

Fig. 1. Typical power spectral density distanced at 48 m.

two spectra. As a result of several measurements for different distances, we got no difference between the spectra as a function of the distance. On the contrary of this evidence, the correlation between two STS-2, distanced at nine, 23 and 37 m, presents obvious difference as a function of numbers of the expansion joint as shown in Fig. 2. The figure shows the degree of correlation between the same Fourier harmonics of the two different signals. Consequently, we have to realign at least 100 μm/month roughly estimated by those empirical rule and ATL [10].

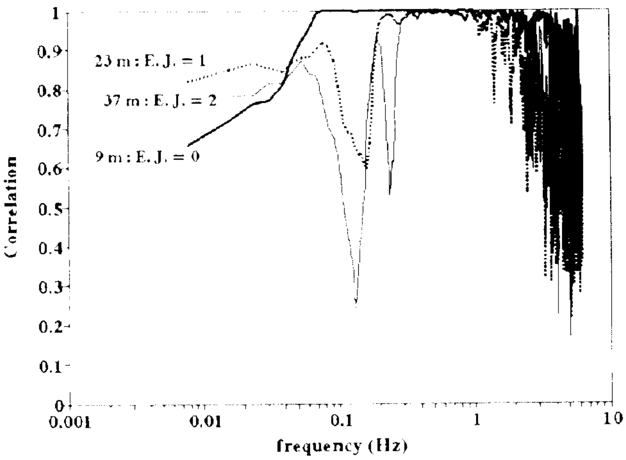

Fig. 2. Correlation between the same Fourier harmonics of the two different signals.

3. VERTICAL LEVEL CORRECTION

3.1. Active Supporting Table

An active supporting table was designed and made to control the position of the magnets for the ATF damping ring, as shown in Fig 3. The table is supported by three remote controllable jacks [1]. The active table has excellent performance and has satisfied the most strict requirements of reproducibility within 5 μm. Same kinds of 36 tables, as shown in Fig. 3, will be set to support the magnet complexes which are schematically described in Fig. 4.

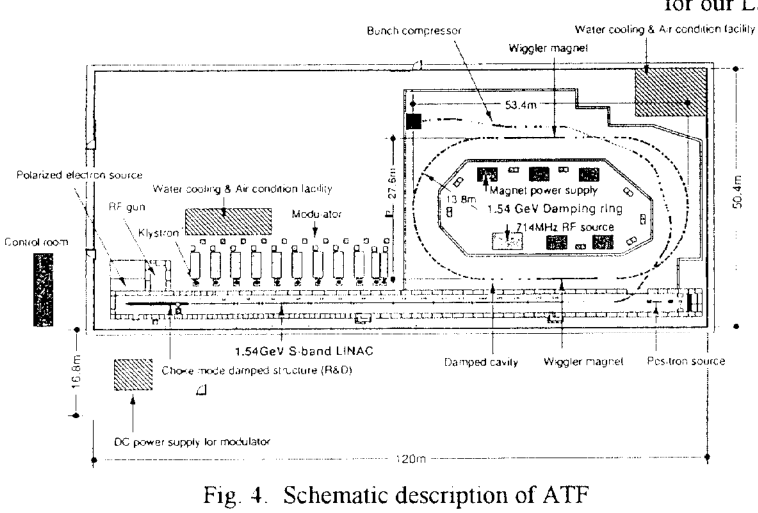

Fig. 4. Schematic description of ATF

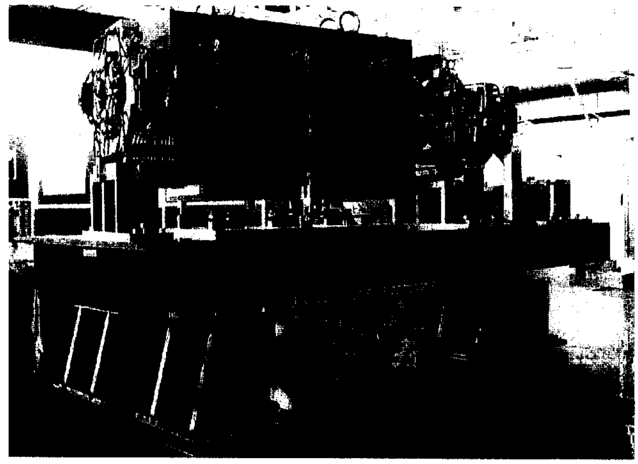

Fig. 3. An active supporting table for the damping ring.

3.2. Leveling System of Half Filled with Water

We use a virtual plane made by free surface of the water to align the magnets of ATF. In order to make the virtual plane, we adopt a Leveling System of Half Filled with water (LSHF) instead of the usually existing Hydrostatic Leveling System (HLS) or water tube tiltmeter [6, 11]. The latter consists of vessels at the ends of the system being connected by a pipe filled with water, while the former pipe is half filled with water. Almost all geophysicists select the tunnel to be independent of temperature, whenever they use the latter type. When they apply the HLS to the accelerator tunnel with this arrangement, temperature changes produce enormous disturbances in the level detection. Figure 5 shows a clear difference between LSHF and HLS. Although height differences are possible to correct partially using the measured temperatures, residual errors inevitably come from the inhomogeneous phase lag between the height signal and the temperature in case of large tangential temperature change. Historically, A. A. Michelson had used the half-filled-tiltmeter for his measurements of the rigidity of the earth [12]. Asada has proposed to apply this idea to the float type water-tube-tiltmeter [13]. We put the capacitive sensor of the HLS (product of FOGALE-Nanotech) to practical use for our LSHF as shown in Fig. 6.

3.3. Height Transfer and Tilt Detection System

LSHF is set as shown in Fig. 6 to make insensitively to chattering of the water surface induced by moving the jacks. In our system, only the table for the magnets is movable using the jacks. A stage for the LSHF is set independently on the side of the active supporting table. The height difference of the magnet center from the virtual plane is detectable through the stage of the LSHF as shown in Fig. 6. Inclinations of the table to the virtual plane are also measured using three LVDTs. The filling and calibrating station for the 36 LSHF is installed outside the tunnel to enable access even when the machine is running.

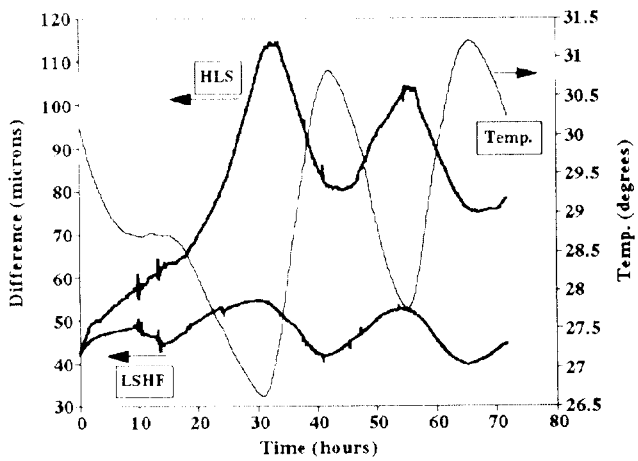

Fig. 5. Comparison filled and half filled with water.

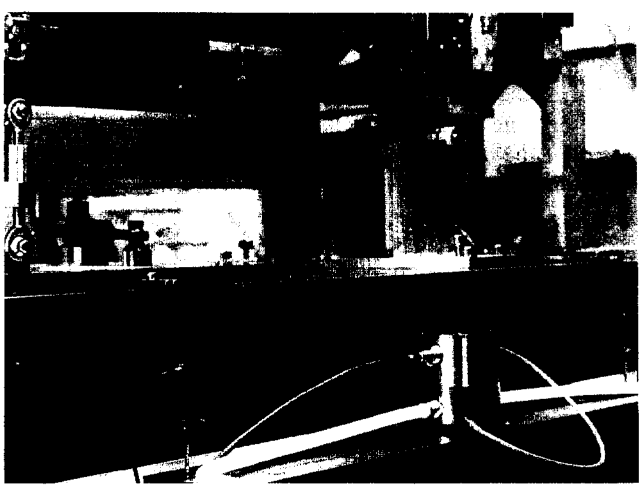

Fig. 6. A leveling system for the damping ring. One LSHF and three LVDTs are installed to every table.

3.4. Electronic Equipment

The Local Operation Network (LON) developed by Echelon Corporation is applied to the control system of the active tables. The heart of LON technology is the neuron chip, a sophisticated VLSI device that incorporates communications, control, scheduling, and I/O support. Figure 7 shows a block diagram of our control system. In a networked control system using LON, intelligent control devices communicate using common protocol. Each device, called a node, in the network contains embedded intelligence that implements the protocol and performs the control functions. In addition, each node includes a media interface that couples the node's microcontroller with the communications medium. The protocol supports distributed, peer-to-peer communication that enables individual network nodes, such as actuators and sensors, to communicate directly with one another. A central control system is not required necessarily.

We use the TP/XF-1250 Control Module to manage analog data from HLS and to send pulses to stepping motors. The TP/XF-1250 module consists of a miniature circuit card which is 61 mm long, 41 mm wide and 18 mm high. The card contains a Neuron 3150 chip, PROM socket, transformer isolated 1.25Mbps Manchester coded communication transceiver, and connectors for power, I/O, and the two wire network data bus. The small size of the module permits it to be mounted on the single size EUROCARD directly adjacent to the 16 bits A/D, pulser, or display of status that the module will control. We are now progressing to test the total system performance.

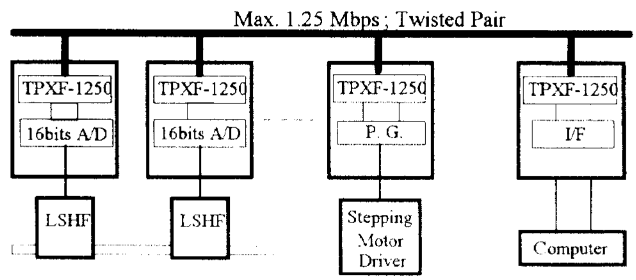

Fig. 7. Block diagram on the control system using LON.

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